Sediment Transport by Internal Waves in EUROSTRATAFORM

David A. Cacchione
CME (Coastal & Marine Environments)
2945 Granite Pointe Drive
Reno, NV 89511
telephone: 775-853-9466 fax: 775-853-9465 e-mail: dcacchione@charter.net

Award Number: N00014-05-M-0056

LONG-TERM GOALS

This project investigates the role that internal waves might have in sediment transport in two field regions in the EUROSTRATAFORM project. The overall long-term project goal is to determine the modes and mechanisms of transport of bottom and suspended sediment by internal waves. The specific goal of this work is to use available and newly acquired data on internal waves and density structure in the Adriatic Sea and Gulf of Lyons to investigate internal wave effects on sedimentation in both regions.

OBJECTIVES

- Evaluate the role of internal waves in resuspending and transporting sediment on the shallow sections of the Adriatic continental shelf off central Italy (water depths < 100 m) and on the shelf and slope off southern France.

- Develop relationships for estimating internal wave-induced bottom stresses that can be applied to sediment transport calculations.

APPROACH

This project is primarily focused on the interaction of internal waves and the seabed. The approach will be similar to the research developed in STRATAFORM (Cacchione, et al, 2002). We are using temperature and current data that was obtained during EUROSTRATAFORM field experiments to estimate internal wave effects on sedimentation. We will develop expressions for internal wave induced bottom stresses that can be used to predict sediment entrainment by internal waves, and that can be applied to modern sedimentation processes in both the Adriatic Sea (“PASTA”) and Gulf of Lyons. Additionally, we will assist with planning and coordination of field experiments in both study areas.

This effort has two principal specific tasks:

(1) development of mathematical expressions for bottom stress by internal waves over sloping bottoms;

(2) analysis of density profiles and time-series temperature and current measurements to investigate internal wave and sediment dynamics in the study areas.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**
4. TITLE AND SUBTITLE **Sediment Transport by Internal Waves in EUROSTRATAFORM**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **CME (Coastal & Marine Environments),2945 Granite Pointe Drive,Reno,NV,89511**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
This project investigates the role that internal waves might have in sediment transport in two field regions in the EUROSTRATAFORM project. The overall long-term project goal is to determine the modes and mechanisms of transport of bottom and suspended sediment by internal waves. The specific goal of this work is to use available and newly acquired data on internal waves and density structure in the Adriatic Sea and Gulf of Lyons to investigate internal wave effects on sedimentation in both regions

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

- Characteristic angles (i.e., group velocity vector directions) have been calculated for internal waves of various frequencies using Brunt Vaisala frequencies determined from density profiles.

- Spectral analyses of velocity and temperature data from PASTA have been completed. The data were obtained on a mooring deployed in about 50 m water depth off Pescara, Italy by Spanish scientists. In particular, analysis of velocity and temperature data showed energetic motions at near-inertial and higher internal wave frequencies.

- An expression for bottom stress due to shoaling high frequency internal waves has been developed and applied to the PASTA region.

- Analysis of large bedforms in the PASTA region and possible causes for these unusual features has been initiated.

RESULTS

The effects of internal waves and tides on transport of bottom and suspended sediment are poorly understood. We have approached this problem both theoretically and using new temperature and current data collected during the first EUROSTRATAFORM field experiment in the Adriatic study area.

We have developed a preliminary model that provides an expression for bottom shear velocity due to high frequency internal waves over a gentle linear bottom slope. The model contains turbulent eddy viscosity (K) and constant Brunt Vaisala frequency (N). The model is based on earlier work of Cacchione and Southard (1974) and Wunsch and Hendry (1974). The details of the model are not shown here, but examples of the model predictions are shown in Figure 1. Assuming N = 4 cph, K = 1 cm^2/s, and bottom roughness z_o = 1 cm, lowest mode small amplitude internal waves with periods of 30 minutes propagating shoreward over a linear bottom slope of 0.5 degrees will produce a bottom shear velocity of ~ 2 cm/s for interior IW velocity (Uint) of 5 cm/s at 50 m water depth. The results of this model suggest that high frequency IWs, if present, can mobilize bottom sediment containing fine to medium sand.

On the PASTA shelf and upper slope regions off the central Italian coast, bottom slopes are typically gentle, ~ 0.05^o to 0.3^o (γ ~ 0.0008 to 0.005). In this region the inertial frequency f ~ 0.056 cph. Values of N determined form PASTA measurements are in the range of 2 cph < N < 16 cph.

In the last Annual Report we showed that near-inertial IWs were critical or near-critical over the gentle slopes of the west-central Adriatic shelf and slope. The near-inertial period T_f of about 17.8 hr is critical along a slope of ~ 0.07^o (or γ ~ 0.001). The temperature and current meter data from the mooring that was deployed along the southern transect in the PASTA experiment (at ~ 50 m water depth) indicate episodic intense near-inertial internal motions, likely caused by low pressure atmospheric events having high surface winds.

Our initial analysis of the intensified near-inertial IW wave events suggests a 3 to 5-fold increase in near-bottom bottom velocities. The current and temperature data show some evidence of this intensification, but we have not completed the analysis to make final interpretations and its relevance for sediment transport.

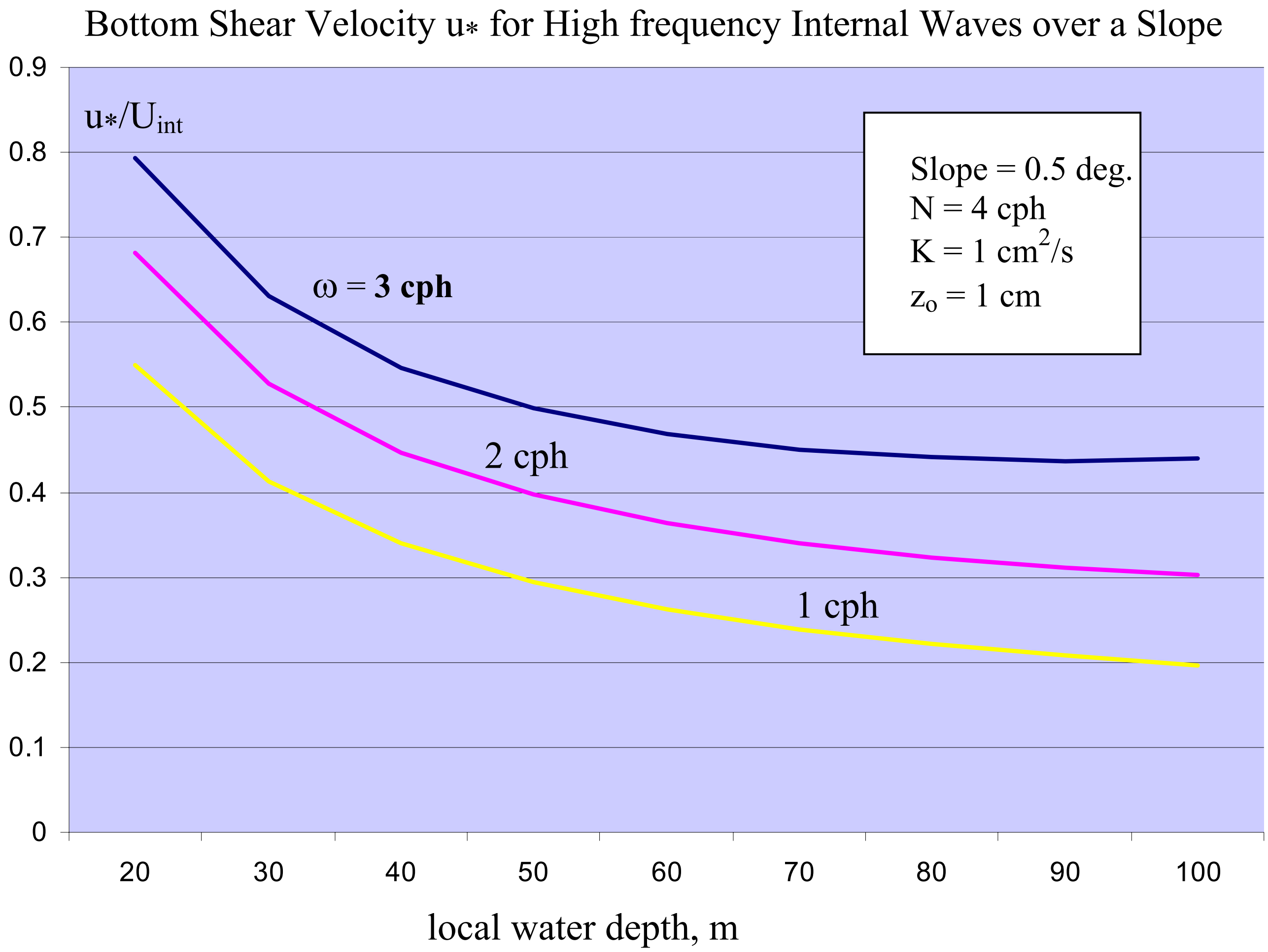

Figure 1. Ratio of bottom shear velocity (u*) and interior internal wave velocity (Uint) for high frequency internal waves over a gentle bottom slope. Based on bottom boundary layer model for constant eddy viscosity (K) and constant Brunt-Vaisala frequency (N). Internal wave frequency (w) << local inertial frequency (f ~ 0.056 cph).

We obtained time-series temperature data at six levels along the mooring that was deployed by Spanish scientists in about 50 m water depth along the southernmost transect off Pescara, Italy. The data were collected at 3 minute intervals in 26, 30, 34, 38, 42 and 46 m water depths from 27 Oct 2002 – 18 Feb 2003. Power spectra show a general increase in energy in the IW band at frequencies between N and f, but also contain curious peaks at lower frequencies (Figure 2).

The energy peaks at about 40, 50 and 72 hours could possibly represent motions caused by internal seiche in the Adriatic Basin (Figure 2). Preliminary estimates of internal seiche periods assuming a cross-basin length scale of 100 km indicate periods of 40-70 hours for 2 or 3 nodes. Future analysis will refine these estimates, and also examine the current meter data for related motions.

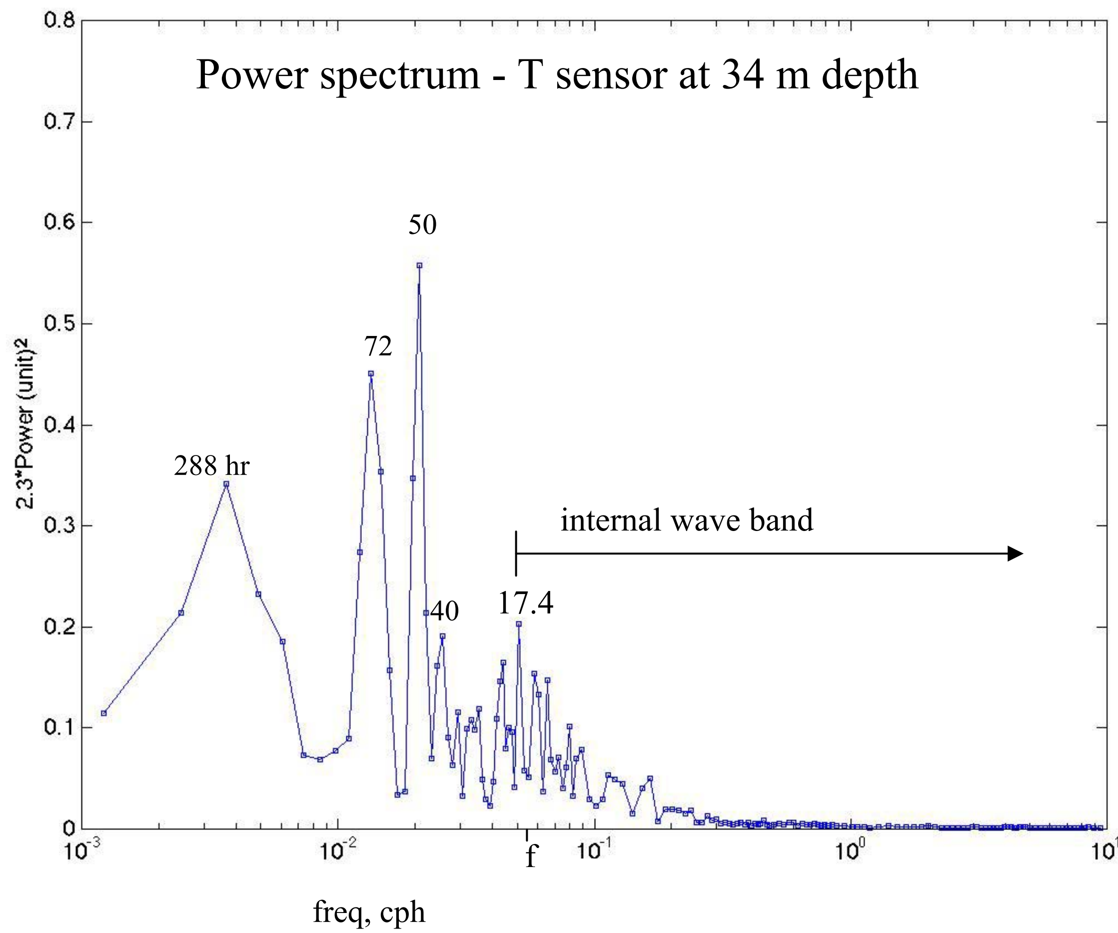

Figure 2. Power spectrum for the temperature data obtained by the sensor mounted in about 34 m depth. Water depth at the mooring site was ~ 50 m. Temperature was sampled every 3 minutes for about 115 days from 27 Oct 2002 – 18 Feb 2003.

Power spectra calculated for the other T sensor data show similar peaks. Other processes such as passage of rapidly moving atmospheric pressure disturbances and associated surface wind shear might cause some of the low frequency energy peaks.

IMPACT/APPLICATIONS

Internal wave-induced bottom stresses might have a major influence on controlling erosion and deposition on shelves and slopes in the oceans and in the Mediterranean Sea. Both high frequency and near-inertial IWs might be important processes for entraining bottom materials and transporting fine sediment. They might also contribute to the formation and modification of bedforms that have been observed along the Adriatic shelf and on the outer shelf in the Gulf of Lyons.

Also, if high frequency internal waves intermittently shoal and break along the seafloor in the seasonal pycnocline, erosion and resuspension of bottom sediment might occur. This process could lead to dispersal of sediment, and generation of turbid bottom layers.

TRANSITIONS

This work has applications for modeling of formation of sedimentary strata and structures on continental shelves. It may also have implications for sedimentation on certain continental shelves where turbulent shears from surface waves and other currents are relatively low (as compared with internal wave effects). The results and model can be integrated into more comprehensive sedimentation models that are under development by others (e.g., J. Syvitski and L. Pratson).

RELATED PROJECTS

The internal wave work is being done in close collaboration with other EUROSTRATAFORM investigators: Dr Pere Puig and Dr. Albert Palanques (both at Ciencies del Mar, Barcelona, Spain), Dr. Andrea Ogston (U. of Washington), Dr. Serge Berne (IFREMER, Brest, France), and Dr. Lincoln Pratson (Duke University).

This project is closely related to those EUROSTRATAFORM projects investigating morphology and surface sedimentation on continental shelves. The work is related to projects led by L. Pratson (Duke University), C. Nittrouer, and A. Ogston (both at University of Washington), J. Syvitski (INSTARR, University of Colorado), and M. Steckler (Lamont-Doherty Geological Observatory).

REFERENCES

Cacchione, D.A. and Drake, D.E., 1986, Nepheloid layers and internal waves over continental shelves and slopes, Geo-Marine Letters, 6, 147-152.

Cacchione, D.A., Pratson, L.F., and Ogston, A., 2002, Science, The shaping of continental slopes by internal tides, 296, 724-727.

McPhee, E.E. and Cacchione, D.A., 1998, Regional characteristics of suspended sediment at intermediate slope depths on the northern California continental slope (abs.), EOS, Trans. AGU, 79 (45), F457.

PUBLICATIONS

Puig, P., Palanques, A., Guillen, J., and D. Cacchione. 2002. The role of near-inertial internal waves in the sediment dynamics of Mediterranean continental shelves, EOS, Trans. Amer. Geophysical Union, Fall Annual Meeting, Abstract Number OS11C-0244.